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THERMAL ANALYSIS AND THERMOVISION LABORATORY TESTS OF ELECTRIC BRAKES

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Abstract

The purpose of this article was to show two thing thermal issues theory and thermovision tests in the laboratory. The main idea of this article was to describe the thermal issues theory of interesting problem base on the thermovision tests of new type electric brake prototype. After the creation of new product the designer needed to know how behave the prototype of the brake during tests with higher energy which could increase the temperatures on the object in our case of the electric brake prototype. The first step in that kind of issues was thermal analysis, which is very useful to define and subscribe the thermal issues. The second step it was measurement of the temperature, which was really significant during the electric brake tests. It was really important to check the temperature of engines. If there was some influence to the brake during braking. One of the method was using special thermal camera. The camera was checking the temperature during whole test after beginning the test to the end of the trial. The full spectrum of the temperature allowed the author to verify if there was some influence of temperature to the new electric brake prototype. The thermocouple was other type of sensors, which was normally used in our laboratory methodology to check temperature during the test. The pyrometer was other type of the method, which was used to measure the temperature after the test. The results of this measurement were subscribed in this article.

Keywords: *laboratory testing, electric brake, temperature tests, braking process, thermovision*

1. Introduction

In modern technology, non-contact, non-invasive methods of machine and device diagnostics are becoming more and more important. Thermovision methods are developing dynamically. They allow assessment of thermal loads, determination of “hot spots” as well as measurements of temperature fields. The purpose of this article was to show the possibility of using thermovision to evaluate the working thermal condition of a modern electric brake and a possible determination of thermal hazards for this system. A simple analysis of the theoretical basis of heat exchange by radiation for the considered temperatures is also presented.

Thermal analysis of the new prototype of electric brake was really important due of checking the influence of the higher temperature to the braking process. Thermal analysis gives a possibility of checking influence, which involve high temperature of the brake parts. In that case, the authors used the thermal camera to register the temperature of brake parts during the test.

2. Thermal analysis theory

For a correct formulation of the task and a selection of a thermovision system, calculations were made for model of black body emissions.

According to Planck’s law, body with a temperature higher than 0 K emits electromagnetic radiation with wavelength ranging from zero to infinity. In the atmosphere, specific wavelengths are absorbed and at the same time particles emit their own radiation.

Thermal imaging systems generally work in the wavelength range from 3 to 11 micrometres.

On the basis of Planck's law, spectral distributions of radiation flux density for temperatures from 300 to 600 K have been determined. For grey bodies' models, their emissivity should be entered. For the materials under consideration, it is about 0.8-0.9. The issues connected with exchanging heat are more subscribed in bibliography positions e.g. [5].

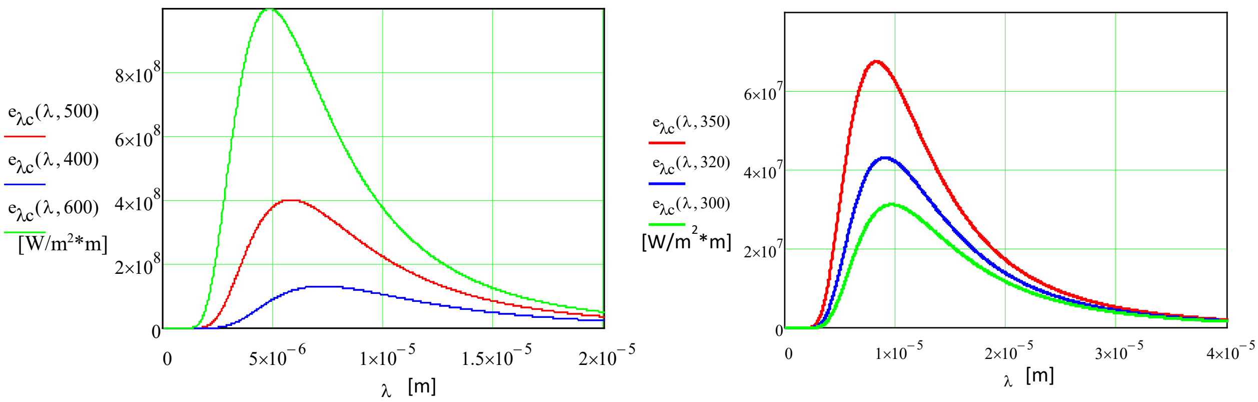

Fig. 1. The distribution of radiation density for a perfect black body of selected temperatures

Based on the graphs of the blackbody radiation, intensity for selected temperatures the amount of energy emitted from the surface at a given temperature is estimated (Stephan Boltzmann) and from the law of Wiena the wavelength is estimated for which we have the maximum radiated energy.

On the basis of Stefan-Boltzmann's law, the power density of radiation was determined as a function of temperature. The results of calculations for the temperature range of 300-700 K are presented in Fig. 2. Based on such considerations, the amount of energy radiated to the environment by the brake elements can be estimated. In the Fig. 3 there were shown the results of calculations based on the law of Wiena.

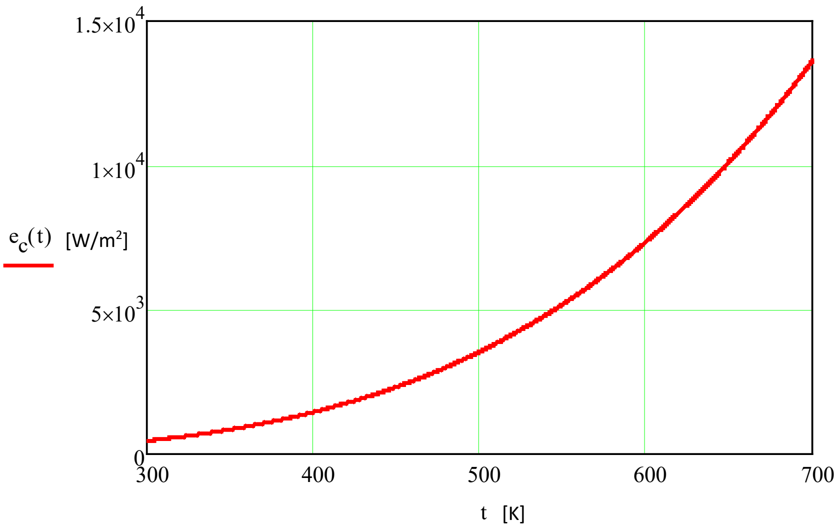

Fig. 2. The power density of radiation as temperature function

As results from these considerations tests of thermal loads of brakes required cameras working in ranges from three to 10 μm. Such considerations also allowed predicting temperature conditions of the system.

The main sets of the thermal imaging device through which the radiation is emitted by the object passes consecutively are:

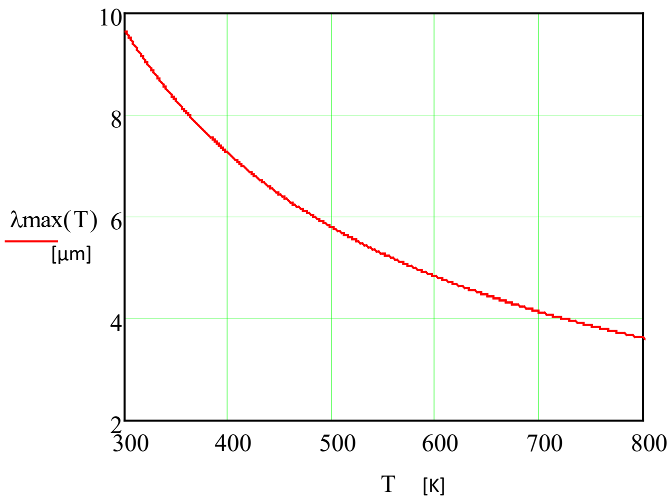

Fig. 3. The wavelengths corresponding to the maximum intensity radiated as a function of temperature

1) the lens,
2) the search system (usually the mechanical-optical system consisting of vibrating or rotating mirrors) whose task is gradual (point by point, line on the line) receiving radiation (information) coming from the observed object,
3) optical system, which focusing radiation,
4) infrared detector.

The detector connected to the amplification circuits produces an electrical signal whose amplitude is proportional to the power of incident radiation. Electric signals are analysed by electronic systems and processed into an image (thermogram) displayed on the screen, which differs from the image of the object observed in visible light.

Thermovision devices receiving and processing microwave radiation emitted by objects (microwave thermography) are used mainly in medical applications or engineering projects.

The thermovision devices can be divided into:

1) observation cameras and measuring cameras (thermal imaging camera),
2) thermal imaging scanners (thermal scanners) – used mainly for observing the area from an airplane or in technological supervision systems (a thermogram is obtained from the assembly of individual lines, with the scanner or object moving perpendicular to the direction of observation),
3) automatic recognition devices – used in automatic target recognition systems (intelligent weapons), in robotics or in automatic surveillance, control and alarm devices.

The main use of the thermovision applications:

– detection of objects in military purposes what could help the troops during performing military tasks. Thermovision cameras can detected planes from a distance of 50 km, tanks from a distance of 20 km and people from a distance of 13 km in a good weather conditions,
– thermal imaging devices allow for contactless remote temperature measurement. This can be used for observing technological processes, for non-destructive testing of materials, construction tests (heating and cooling devices, machines, buildings) and semiconductor devices structures for temperature control of various elements (insulators, transformers, fuses, cables) during work as well as to study the effectiveness of pharmacological agents (e.g. the effect of drugs on blood supply to tissues),
– thermovision applications are used in medical diagnostics. It is a completely non-invasive method of detecting breast cancer, imaging inflammatory conditions of sinuses, teeth, veins, lungs, joints, thyroid gland and others. Thermal imaging cameras are used during open-heart surgery (observation of blood flow through the veins and arteries).

History of using thermovision technology is started in 19th century. Since 1833, projects have connected infrared radiation and have used it for communication and detection of objects. First army cameras were used in fifties in 20th century. Since than methods of using thermovision have evolved and the devices have upgraded [6].

3. Laboratory test stand

The full-scale electric brake was tested on Młot-3T test stand (Fig. 4) in laboratory where the real braking conditions were imitated. This test allowed checking the new prototype designing in full scale in real conditions. Młot 3T tests were required to evaluate brake design and to prove the efficiency and reliability. Test stand allowed the researcher to change the parameters in order to evaluate behaviour of the brake. Parameters of the test stand are shown in Tab. 1.

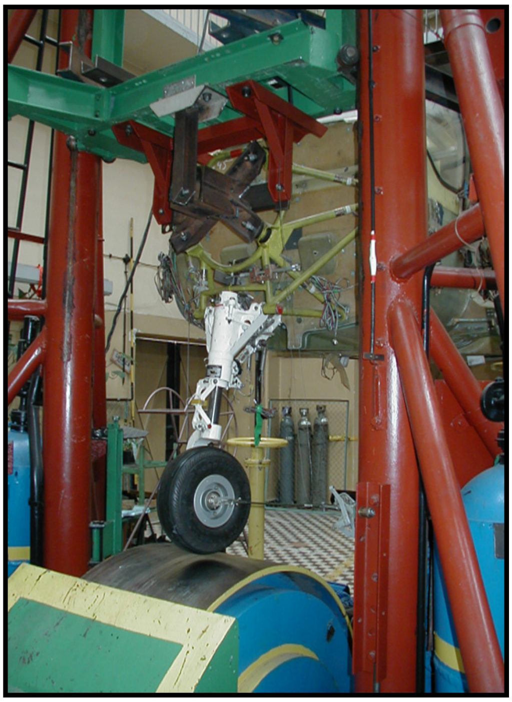

Fig. 4. Test stand Młot 3T, source ILot

Tab. 1. Młot 3T Technical Data

Technical data		
Maximal weight of tested object including mounting parts		3T
Maximal vertical force during the tests		118 kN
Maximal buffer pressure		1.96 MPa
Drum maximal rotational speed		800 rpm (13.3 rps)
Drum maximal peripheral speed		211 km/h (58.6 m/s)
Drum exterior diameter		1400 mm
Drum width		530 mm
Buffer force		0-22.2 kN
Moment of Inertia	I1 = Ib	294 kgm^2
	I2 = Ib + Il	550 kgm^2
	I3 = Ib + Ip	588 kgm^2
	I4 = Ib + Il + Ip	843 kgm^2

4. Laboratory temperature tests

In the braking test, the temperature was measured after braking. The engines were around 30°C. The motors were not very hot after the test. One form of the tests it was the test of clutching of the brake linings on the brake disc, which was continue for of 45 minutes. The loads were applied to the engines to operate for a longer time than normal braking. The temperature of brake motors built up to 45°C what was measured. This situation is not anticipated in normal conditions of use. However, such the test was made to check the engines.

Tab. 2. Results of temperatures tested brake

No.	P [daN]	I_b [kgm^2]	E_h [J]	a_s [rpm/s]	N [rpm]	t [s]	T_{tarczy} [°C]	Comments
1	349	588	34530.49	1000	104	8	50	
2	349	588	77693.61	1000	156	10	84.5	
3	349	588	138121.96	1000	207	14	131	
4	349	588	34530.49	5000	104	6	44.7	
5	349	588	77693.61	5000	156	8	75	
6	349	588	138121.96	5000	207	11	134.8	
7	349	588	174810.61	5000	233	14	167	
8	349	588	215815.57	5000	259	15	190	
9	349	588	**276558.28**	5000	294	17	270	

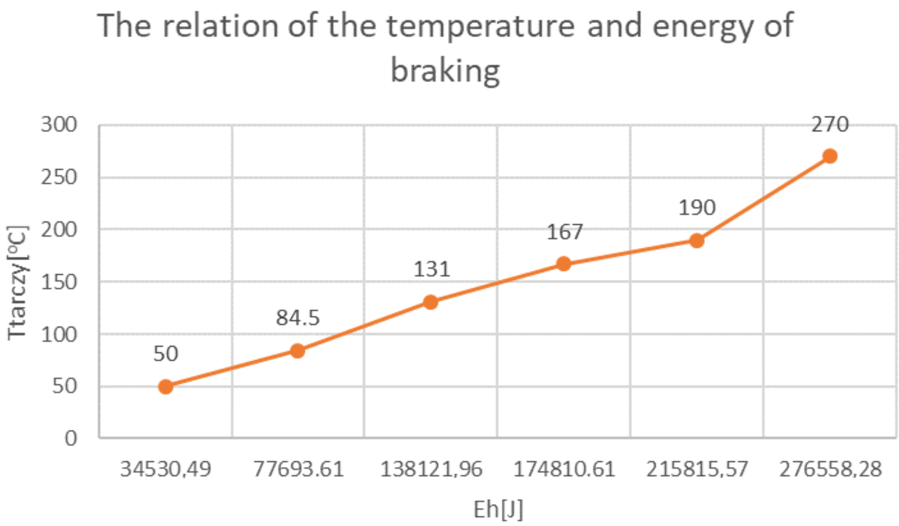

Fig. 5. The graphs of relation of the temperature of the disc and energy of braking

During the tests, the temperature was checked after the every trial by pyrometer. In different tests, the temperature of disc was changed because the energy of every test increased. The results are shown in Tab. 2. The most important is relation of temperature and energy of braking which was shown on Fig. 5. As a result, the temperature of braking disc increased while the energy of braking increased.

Another aspect of the thermal analysis was the test of temperature determination using a FLIR SC645 thermal imaging camera with an image recording frequency of fr = 25 Hz. The dedicated FLIR ReasearchIR software was used to record the image (Fig. 6).

Thermal camera is a device that measures infrared radiation of object surface. Amount of emitted radiation depends of actual body temperature. Intensity of radiation depends of objects material; and it is called emissivity [4].

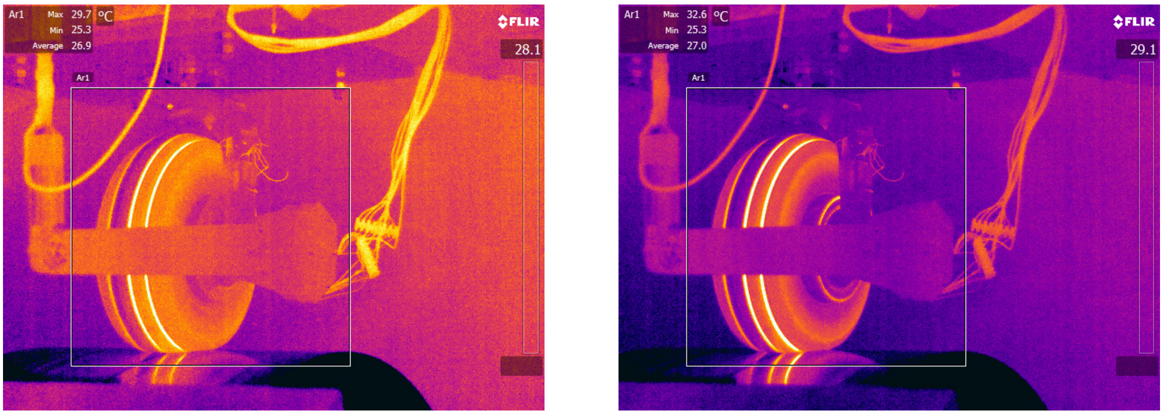

Fig. 6. View from the thermal camera

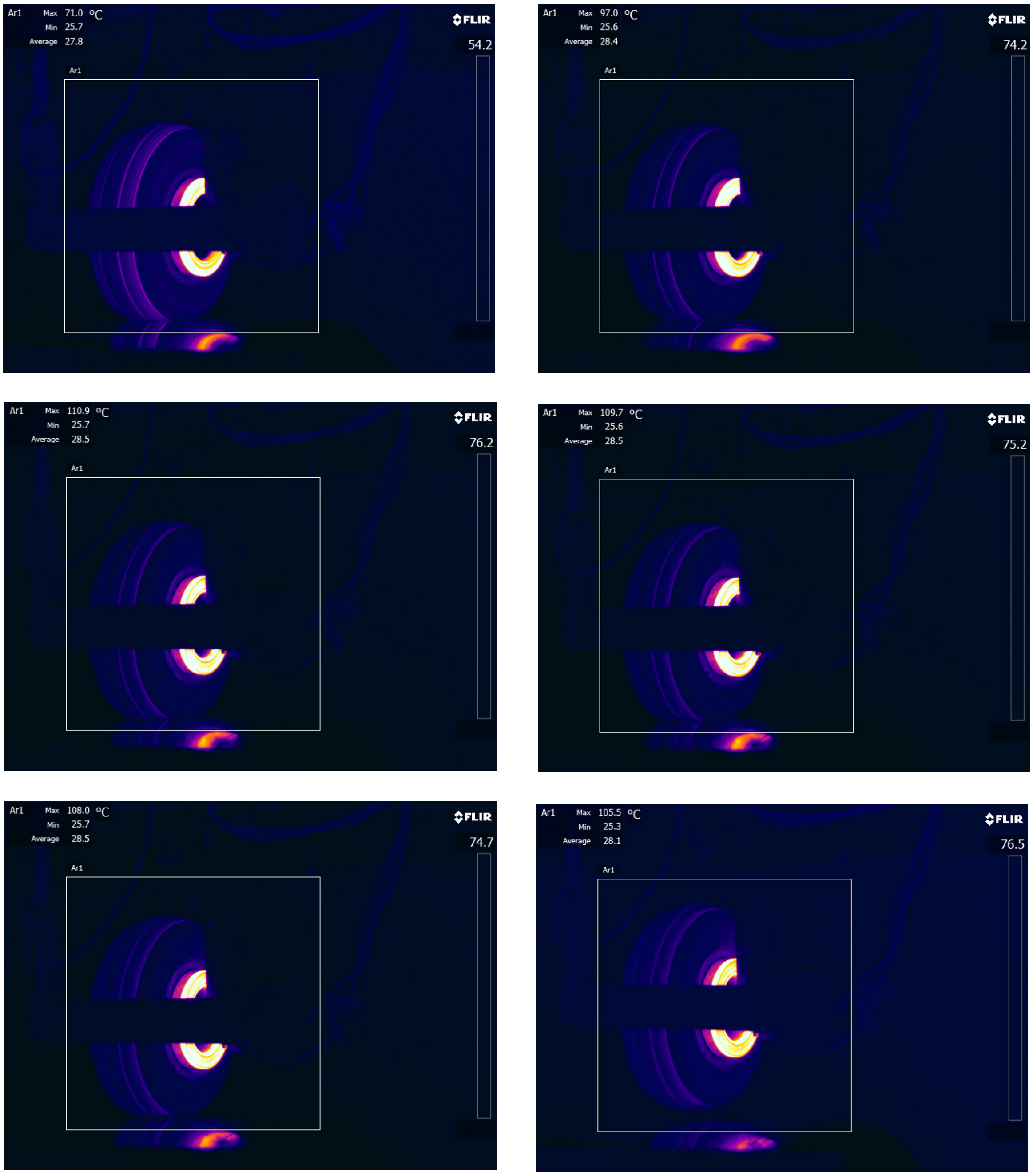

Fig. 7. View from the thermal camera during the test

5. Summary

The main idea of this article was to show the thermovision issues in theory and in practice. Some of the selected theoretical issues were subscribed for example energy emitted from the surface of part. The working of the thermovision camera was approximated using theoretical knowledge. The methods of measure the temperature were different but nowadays seem to be really simple to use thermovision to check temperature of the testing object.

Final analysis of the working conditions of tested brake systems showed that for considered working parameters there were no "bad" influence on the engine and electric equipment. The temperature of the brake disc increased because the energy of braking increased so this is normal situation but thermal loads not caused any damages in system. The infrared camera is a very useful tool for diameter of working elements.

All of the tests and analysis described in this article were performed in the Landing Gear Laboratory of Institute of Aviation in Warsaw.

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